

Two new species of Pinwheel Snail from contrasting Queensland habitats and a redescription and generic re-assignment of *Gyrocochlea myora* Stanistic, 2010 (Gastropoda: Eupulmonata: Charopidae)

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ABSTRACT

Two new species of Charopidae are described from contrasting Queensland habitats. *Lithocouperia kalkajaka* gen. et sp. nov. lives among the granitic lithoreugia of Kalkajaka (=Black Mountain), Trevethen Range, NEQ. *Reticularopa minjerribah* gen. et sp. nov. chiefly inhabits the Blackbutt (*Eucalyptus pilularis*) and Scribbly Gum (*Eucalyptus racemosa*) sand-based, woodland communities of Minjerribah (=North Stradbroke Island), SEQ. A third species, '*Gyrocochlea*' *myora* Stanistic, 2010 known only from a small patch of rainforest along the Myora-Dunwich Road, Minjerribah, SEQ is redescribed and re-assigned to *Chordaropa* gen. nov. The use of protoconch microsculpture for determining generic units within the family is discussed. □ new genera, new species, new combination, Gastropoda, Charopidae, Queensland.

The Charopidae (Pinwheel Snails) is a family of tiny snails (mostly 1.5-5 mm shell diameter) of Gondwanan origin widely distributed on land masses in the Southern Hemisphere (Australia, New Zealand, South Africa and South America) and some Pacific islands. In Australia the family has its greatest diversity in the rainforests of eastern Australia (Queensland, New South Wales, Victoria and Tasmania); a very small number of species also exist in South Australia, Western Australia and the Red Centre (Smith 1992, Stanistic *et al.* 2010). The family was traditionally considered as being largely restricted to the temperate areas of south-eastern Australia. However, since 1980 large numbers of species have been collected from the subtropical and tropical regions of eastern

Australia including approximately 80 species from the Wet Tropics Bioregion alone (Stanistic, pers. obs.). Most eastern Australian charopids have restricted distributions in wet forests and dry vine thickets with very few species having made the transition to the drier eucalypt forests where greatest diversity tends to be centered around isolated limestone habitats (Hyman & Stanistic 2005). Although there have been several major descriptive efforts at documenting new species since the late 1980's (Stanistic 1990, Hyman & Stanistic 2005, Stanistic *et al.* 2010, Shea *et al.* 2012) much of the Australian charopid fauna remains undescribed.

This study describes two new species of charopid from contrasting subtropical and tropical habitats in eastern Queensland and



FIG. 1. Granitic boulders and rainforest, Kalkajaka (=Black Mountain), north Queensland. Taken from Moulds & Olive (2014). Image: Fanie Venter.

redescribes and re-assigns one of the many 'Gyrocochlea' species introduced by Stanisic *et al.* (2010). The three species included in this study are all allocated to new generic units within the family based on their novel patterns of protoconch sculpture. The species all fit the *Gyrocochlea* grade of shell organisation but differ dramatically in protoconch sculpture from that of true *Gyrocochlea* (type species: *Helix vinitincta* Cox, 1868) whose species are centred on the NSW/Qld Border (Stanisic 1990, Shea *et al.* 2012). They also differ in protoconch sculpture from the many patterns displayed by the other 'Gyrocochlea-like' genera cited in Stanisic (1990), Hyman & Stanisic (2005) and Shea *et al.* (2012).

MATERIAL AND METHODS

Material used in this study is held in the mollusc collections of the Queensland Museum (QMMO). Measurements of shell height, diameter and umbilical width were made using Wild M5 stereo-microscope with a calibrated eyepiece. Only specimens with four whorls and above were measured. Whorl counts were

made to the nearest 1/8 whorl. High resolution images of shells (260-600MB) were taken with a Visionary Digital BK-Plus lab system camera setup in the Queensland Museum's Digital Imaging Unit. Reproductive systems of all spirit specimens were examined but all were found to be immature.

Abbreviations used: NEQ, north-eastern Queensland; NSW, New South Wales; Qld, Queensland; RC, dry collection; SC, spirit collection; SEM, scanning electron microscopy; SEQ, south-eastern Queensland; SSE, south south-east; H/D, height ratio to diameter; D/U, diameter ratio to umbilical.

SYSTEMATICS

Infraorder EUPULMONATA

Superfamily PUNCTOIDEA

Family CHAROPIDAE

Genus *Lithocouperia* gen. nov.

Type species. *Lithocouperia kalkajaka* sp. nov.-herein designated.

Etymology. A contraction of lithorefugia, and for Patrick Couper who first introduced the former term into the literature.

Diagnosis. Shell small (large for family), light brown, discoidal with a strongly sunken spire; protoconch sculpture of numerous, closely spaced, spiral rows of tiny raised tubercles, teleoconch with moderately spaced protractively sinuate radial ribs, 40 on first adult whorl; microsculpture of numerous, closely spaced, fine radial threads crossed by equally fine spiral threads; aperture ovately lunate; umbilicus wide cup-shaped.

Lithocouperia kalkajaka sp. nov.
(Figs 2A-C, 6A, 7D, Table 1)

Etymology. Kalkajaka, the local indigenous name for Black Mountain, traditional home of the Kuku Nyungkul people.

Preferred common name. Kalkajaka Pinwheel Snail.

Material examined. Holotype. QMMO80719, Black Mtn, S of Cooktown, FNQ, 15°39'S, 145°13'E, patchy

Pinwheel Snails

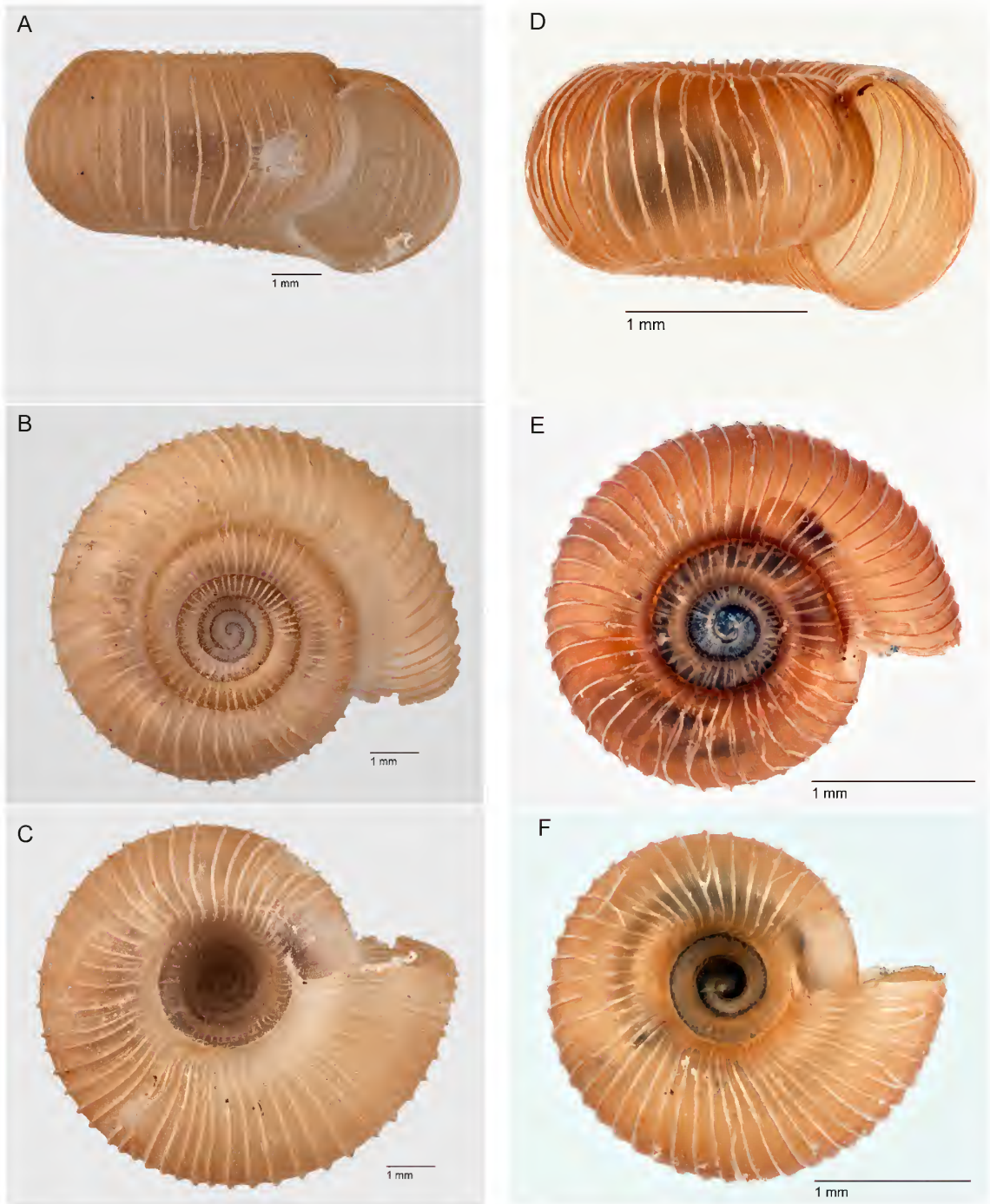


FIG. 2. A-C. *Lithocouperia kalkajaka* sp. nov., QMMO80719, holotype; D-F. *Reticularopa minjerribah* sp. nov., QMMO80720, holotype. Scale lines as marked.



FIG. 3. Scribbly Gum forest on sand, SE Dunwich, Minjerribah, SEQ.

vine thicket/granite boulders, 8.xi.1995, coll. G. Monteith, D. Cook, H. Janetzki, L. Roberts. Diameter of shell 8.75 mm, height 4.37 mm, umbilical width 2.83 mm, H/D 0.50, D/U 3.09, number of whorls 5.675.

Paratypes. (All subadult). QMMO78703, 2SC/1RC, same data as holotype.

Diagnosis. As for genus.

Description. Shell small, light brown, discoidal with a strongly sunken spire; whorls 5.675 tightly coiled, shouldered above and rounded below the periphery, last not descending in front; sutures strongly impressed. Height of shell 4.37 mm, diameter 8.75 mm, H/D 0.50. Protoconch flat, of 1.75 whorls sculptured with numerous crowded, spiral rows of tiny tubercles, teleoconch sculpture of moderately spaced protractively sinuate radial ribs, 40 on first adult whorl, 53 on body whorl. Microsculpture of numerous very fine radial riblets (35-40 between each pair of major ribs on body whorl) crossed by equally prominent and fine spiral threads. Aperture ovately lunate, lip simple. Umbilicus wide cup-shaped, diameter 2.83 mm, D/U 3.09. Based on one adult specimen (QMMO80719).

Reproductive anatomy unknown. All spirit specimens (QMMO78703) immature.

Habitat and ecology. Scattered patches of vine thicket with occasional *Ficus* sp.; living among granite boulders (Fig. 1).

Remarks. *Lithocouperia kalkajaka* sp. nov. is known only from the granite boulders (lithorefugia) of Kalkajaka (=Black Mountain), south of Cooktown, NEQ. It is the second largest Australian charopid recorded, eclipsed in size only by *Gyrocochlea vinitincta* (Cox 1868) from southern Queensland which has a recorded maximum diameter of 9.75 mm (Shea *et al.* 2012). The protoconch sculpture of *L. kalkajaka* is comparable with the finely cancellate sculpture seen on the protoconch of *Gyrocochlea* Hedley, 1924 from the Border Ranges of New South Wales-Queensland but differs most notably in having spiral rows of tiny tubercles without a radial component (Fig. 6A). This is a unique pattern among the Australian charopid protoconchs hitherto examined by SEM, including a number from the Wet Tropics Bioregion.

Reticularopa gen. nov.

Type species. *Reticularopa minjerribah* sp. nov.-herein designated.

Etymology. From the Latin *reticulata* = net, and a contraction of *Charopa*; referring to the net-like configuration of the protoconch sculpture.

Diagnosis. Shell tiny, brown, discoidal with a strongly sunken spire; protoconch sculpture of prominent widely spaced, sinuate radial ribs crossed by equally prominent and widely spaced spiral lirae and forming a distinct bead at their intersection, teleoconch with moderately spaced, protractively sinuate radial ribs, 39-48 on first adult whorl; microsculpture of fine radial riblets and low spiral cords; aperture ovately lunate; umbilicus wide cup-shaped.

Reticularopa minjerribah sp. nov. (Figs 2D-F, 6C, 7E, Table 1)

Etymology. Minjerribah, the local indigenous name for North Stradbroke Island, traditional home of the Quandamooka people.

Preferred common name. Minjerribah Pinwheel Snail.

Pinwheel Snails

TABLE 1. Shell measurements of *Lithorefugia kalkajaka* sp. nov., *Reticularopa minjerribah* sp. nov. and *Chordaropa myora* Stanisic, 2010 comb. nov.

Taxon	N	Diameter (mm)	Height (mm)	Umbilical width (mm)	H/D ratio	D/U ratio	Number of whorls
<i>L. kalkajaka</i> sp. nov.							
QMMO80719 holotype	1	8.75	4.37	2.83	0.50	3.09	5.675
<i>R. minjerribah</i> sp. nov.							
QMMO80720 holotype	1	2.56	1.35	0.81	0.52	2.73	4
QMMO70511	4	2.34-2.50	1.25-1.31	0.88-0.94	0.52-0.54	2.33-2.79	4-4.125
QMMO70517	5	2.38-2.66	1.28-1.34	0.78-0.88	0.49-0.54	2.29-3.40	4-4.5
QMMO70442	2	2.46-2.56	1.25-1.34	0.84-0.88	0.51-0.53	2.93	4-4.25
QMMO70446	2	2.34-2.41	1.25	0.78	0.52-0.53	3.00-3.08	4-4.25
<i>C. myora</i> Stanisic, 2010							
QMMO20783 holotype	1	5.84	2.60	1.30	0.45	4.49	4.75
QMMO16819	2	4.09-4.54	2.14-2.27	1.30	0.50-0.52	3.15-3.49	4.25

Material examined. (All North Stradbroke Island, SEQ). Holotype. MO80720, SSE Dunwich, rainforest patch beside 18 Mile Swamp, 27°35'34"S, 153°27'50"E, in litter among bark, 5 m, coll. J Stanisic, D. Potter, 9.i.2002. Diameter of shell 2.56 mm, height 1.35 mm, umbilical width 0.81 mm, H/D 0.53, D/U 3.16, number of whorls 4.

Paratypes. QMMO70517, 35RC, same data as holotype; QMMO70442, 11RC, SSE Dunwich at Enterprise Mine Site, Scribbly Gum 2 Site, 27°36'48"S, 153°26'1"E, in litter among bark, 120 m, coll. J. Stanisic, D. Potter, 8.i.2002; QMMO70446, 1SC/7RC, SSE Dunwich at Enterprise Mine Site, Blackbutt 1 Site, 27°33'3"S, 153°27'34"E, in litter among bark, 90 m, coll. J. Stanisic, D. Potter, 8.i.2002; QMMO70511, 9RC, SSE Dunwich at Enterprise Mine Site, Blackbutt 3 Site, 27°34'33"S, 153°27'57"E, in litter among bark, 80 m, coll. J. Stanisic, D. Potter, 9.i.2002.

Other material. QMMO70438, 1RC, SSE Dunwich at Enterprise Mine Site, Mallee 1 Site, 27°34'27"S, 153°26'20"E, in litter among bark, 120 m, coll. J. Stanisic, D. Potter, 8.i.2002; QMMO70439, 4RC, SSE Dunwich at Enterprise Mine Site, Mallee 2 Site, 27°35'24"S, 153°26'35"E, in litter among bark, 100 m, coll. J. Stanisic, D. Potter, 8.i.2002; QMMO70440, 4RC, SSE Dunwich at Enterprise Mine Site, Mallee 3 Site, 27°35'49"S, 153°26'23"E, in litter among bark, 80 m, coll. J. Stanisic, D. Potter, 8.i.2002; QMMO70441, 6RC, SSE Dunwich at Enterprise Mine Site, Scribbly Gum 1 Site, 27°36'44"S, 153°26'27"E, in litter among bark, 70 m, coll. J. Stanisic, D. Potter,

8.i.2002; QMMO70443, 10SC/5RC, SSE Dunwich at Enterprise Mine Site, Scribbly Gum 3 Site, 27°35'35"S, 153°27'09"E, in litter among bark, 70 m coll. J. Stanisic, D. Potter, 8.i.2002; QMMO70447, 6RC, SSE Dunwich at Enterprise Mine Site, Blackbutt 2 Site, 27°33'37"S, 153°27'06"E, in litter among bark, 60 m, coll. J. Stanisic, D. Potter, 8.i.2002; QMMO70501, 1RC, SSE Dunwich at Enterprise Mine Site, Mallee 3 Site, open woodland, 27°35'49"S, 153°26'23"E, in litter, 80 m, C. Burwell, 8.i.2002; QMMO70502, 1RC, SSE Dunwich at Enterprise Mine Site, Blackbutt 1 Site, open woodland, 27°33'23"S, 153°27'34"E, in litter, 90 m, C. Burwell, 8.i.2002.

Diagnosis. As for genus.

Description. Shell tiny, discoidal, brown with a strongly sunken spire; whorls 4-4.5, tightly coiled, shouldered above and rounded below the periphery, last not descending in front; sutures strongly impressed. Diameter of shell 2.34-2.66 mm (mean 2.46 mm), height 1.25-1.35 mm (mean 1.29 mm), H/D 0.49-0.54 (mean 0.53 mm). Protoconch flat, of 1.5 whorls sculptured with prominent, widely spaced sinuate radial ribs crossed by equally prominent and widely spaced spiral lirae forming a distinct bead at their intersection, teleoconch sculpture of moderately spaced to crowded, protractively

sinuate radial ribs, 39-48 (mean 42) on first adult whorl, 50-96 (mean 69) on body whorl. Microsculpture of numerous very fine radial riblets, 15-20 between each pair of major ribs on body whorl, and low spiral cords. Aperture ovately lunate, lip simple. Umbilicus wide cup-shaped, diameter 0.78-0.94 mm (mean 0.85 mm), D/U 2.29-3.40 (mean 2.83). Based on 14 adult specimens (QMMO70442, 70446, 70511, 70517, 80720).

Reproductive anatomy unknown. All spirit specimens (QMMO70443, 70446) immature.

Habitat and ecology. Scribbly Gum and Blackbutt forest communities on sand; living among discarded bark and scattered timber (Fig. 3).

Remarks. *Reticularopa minjerribah* sp. nov. is only known from Minjerribah (=North Stradbroke Island), SEQ where it occurs widely in the woodland communities (Scribbly Gum, Blackbutt, Mallee) on sand. It is also found in a small patch of rainforest on sand at Eighteen Mile Swamp but not from the rainforest at Dunwich-Myora. This patch of forest is considered to have opportunistically developed on a patch of organically rich, humic sand on the edge of swampland. Protoconch features of *R. minjerribah* compare broadly with those of *Dictyoropa* Shea *et al.* 2012 (type species: *Gyrocochlea eurythma* Hedley, 1924) from the northern rivers area of NSW but differ in having the radial and spiral elements more defined and more widely spaced giving rise to a more open lattice network (Fig. 6C, D). The reticulate pattern of *R. minjerribah* is also present in several undescribed species from the adjacent mainland suggesting that this species may be part of a broader local radiation (Fig. 7C). The larger lots of specimens in the Queensland Museum include many with whorl counts less than four which is considered to constitute an immature shell (Stanisic 1990). Hence, the lack of measured specimens.

Chordaropa gen. nov.

Type species. *Gyrocochlea myora* Stanisic, 2010-herein designated.

Etymology. From the Greek *chorda* = cord, and a contraction of *Charopa*; referring to the low, broad, rope-like spiral cords on the protoconch.

Diagnosis. Shell tiny, light brown to beige, discoidal with a flat to slightly sunken spire; protoconch sculpture of low, broad spiral cords and weaker, curved radial ridges that become increasingly prominent toward the protoconch-teleoconch boundary, teleoconch with crowded, weakly protractively sinuate radial ribs, 90-110 on first adult whorl; microsculpture of fine radial riblets and low spiral cords; aperture ovately lunate; umbilicus wide U-shaped.

Remarks. *Chordaropa* gen. nov. differs from *Gyrocochlea* s.s. by having low, broad spiral cords and weak, curved radial ridges which contrast vividly with the distinctly fine, cancellate pattern seen in the latter. This difference is equivalent to the differences between *Gyrocochlea* s.s. and some of the new genera of Shea *et al.* (2012) and is herein considered sufficient to justify the introduction of a new genus for '*Gyrocochlea*' *myora* Stanisic, 2010.

Chordaropa myora Stanisic, 2010 comb. nov. (Figs 5A-C, 6E, 7F, Table 1)

Gyrocochlea myora Stanisic 2010 (in Stanisic *et al.* 2010, sp. 286)

Preferred common name. Myora Pinwheel Snail.

Material examined. Holotype. QMMO20783, c. 2 km NE Dunwich on Dunwich-Myora road, North Stradbroke I., SEQ, 27°29'S, 153°24'E, rainforest, in litter, coll. J. Stanisic, 23.iii.1989. Diameter of shell 5.84 mm, height 2.60 mm, umbilical width 1.30 mm, H/D 0.45, D/U 4.49, whorls 4.75.

Paratypes. QMMO78948, 2RC, same data as holotype; QMMO16819, 19RC/65C, Myora, Stradbroke I., SEQ, rainforest, under logs, coll. J. Stanisic, 29.i.1984.

Diagnosis. As for genus.

Description. Shell tiny, discoidal with a flat to slightly sunken; whorls 4.25-4.75, tightly coiled, shouldered above and rounded below the periphery, last slowly descending in front; sutures strongly impressed. Diameter of shell



FIG. 4. Rainforest, Myora, Minjerribah, SEQ. Image: John Stanisic.

4.09–5.84 mm (mean 4.82 mm), height 2.14–2.60 mm (mean 2.34 mm), H/D 0.45–0.52 (mean 0.49). Protoconch flat, of 1.5 whorls sculptured with low, broad spiral cords and weaker, curved radial ridges that become increasingly prominent toward the protoconch-teleoconch boundary, teleoconch with very crowded, weakly protractively sinuate radial ribs, 90–110 on first adult whorl, 210–240 on body whorl. Microsculpture of numerous very fine radial riblets (approximately 10 between each pair of major ribs on body whorl) and low spiral cords. Aperture ovately lunate, lip simple. Umbilicus wide U-shaped, diameter 1.30 mm, D/U 3.15–4.49 (mean 3.71). Based on three adult specimens (QMMO16819, 20783).

Reproductive anatomy unknown. All spirit specimens (QMMO16819) immature.

Habitat and ecology. Rainforest; living under logs (Fig. 4).

Remarks. *Chordaropa myora* Stanisic, 2010 comb. nov. can be readily distinguished from the more widespread *R. minjerribah* by

a combination of larger shell size, flat spire, more intense teleoconch ribbing and U-shaped rather than wide cup-shaped umbilicus. The species is found in the closed forest (= rainforest) community in the Dunwich-Myora area. The protoconch pattern in *C. myora* is broadly similar to that of *Diphyoropa* Hyman & Stanisic 2005 (type species: *Helix saturni* Cox, 1864) in that it is initially spiral with radial ribs becoming prominent on the latter half of the protoconch. However, the spiral elements of *C. myora* are more crowded and much less distinct than those of *Diphyoropa*. A similar protoconch pattern is present in '*Gyrocochlea cinnamea* (Hedley, 1912) from Coolabunia, SEQ (Fig. 7A) and several other undescribed eastern Queensland charopids (Stanisic, unpubl.). The pattern in *Chordaropa* is somewhat similar to that of *Comboyneia* Shea *et al.*, 2010 (type species: *Comboyneia boorganna* Shea, Colgan & Stanisic, 2012) from mid-east NSW (Fig. 7B) which also has similar spiral cords on the protoconch but which lacks the curved radial ridges.

GENERAL REMARKS

The description of two new species of Charopidae highlights two contrasting and unusual habitats for a family better known from rainforest and wet sclerophyll environments in eastern Australia (Stanisic *et al.* 2010). *Lithocouperia kalkajaka* sp. nov. lives among the granitic lithorefugia of Kalkajaka (=Black Mountain), Trevethen Range, NEQ. The Trevethen Range is located about 25 km south of Cooktown in the northern-most extension of the Einasleigh Uplands Bioregion and is also geographically adjacent to the Wet Tropic Bioregion. *Reticularopa minjerribah* sp. nov. chiefly inhabits the Blackbutt (*Eucalyptus pilularis*) and Scribbly Gum (*Eucalyptus racemosa*) sand-based, woodland communities of Minjerribah (= North Stradbroke Island), SEQ. A third species, '*Gyrocochlea*' *myora* Stanisic, 2010 known only from a small patch of rainforest at Myora-Dunwich Road, Minjerribah, SEQ is redescribed and re-assigned to *Chordaropa* gen. nov.

Lithocouperia kalkajaka sp. nov. displays a number of unusual features which distinguish it from other hitherto described charopids from the Einasleigh Uplands Bioregion and those from the northern reaches of the Wet Tropics Bioregion (Stanisic *et al.* 2010). The unusual architecture of the protoconch microsculpture (microtubercles) and the very large size (for the family) are a combination of shell features that also distinguish it from all other Queensland charopids. This species may be another endemic Kalkajaka invertebrate following on the recent description of the cicada *Tamasa caverna* Moulds & Olive, 2014. Charopids reach their northern limits in the Cooktown area and only one undescribed species is known from Cape York Peninsula (Stanisic, pers. obs.). The large numbers of undescribed species from the Wet Tropics may yet hold the key to origins of this most unusual charopid.

Reticularopa minjerribah sp. nov. and *Chordaropa myora* comb. nov. inhabit contrasting environments on Minjerribah and display contrasting shell morphologies. *R. minjerribah* from the sand-based woodland communities SSE

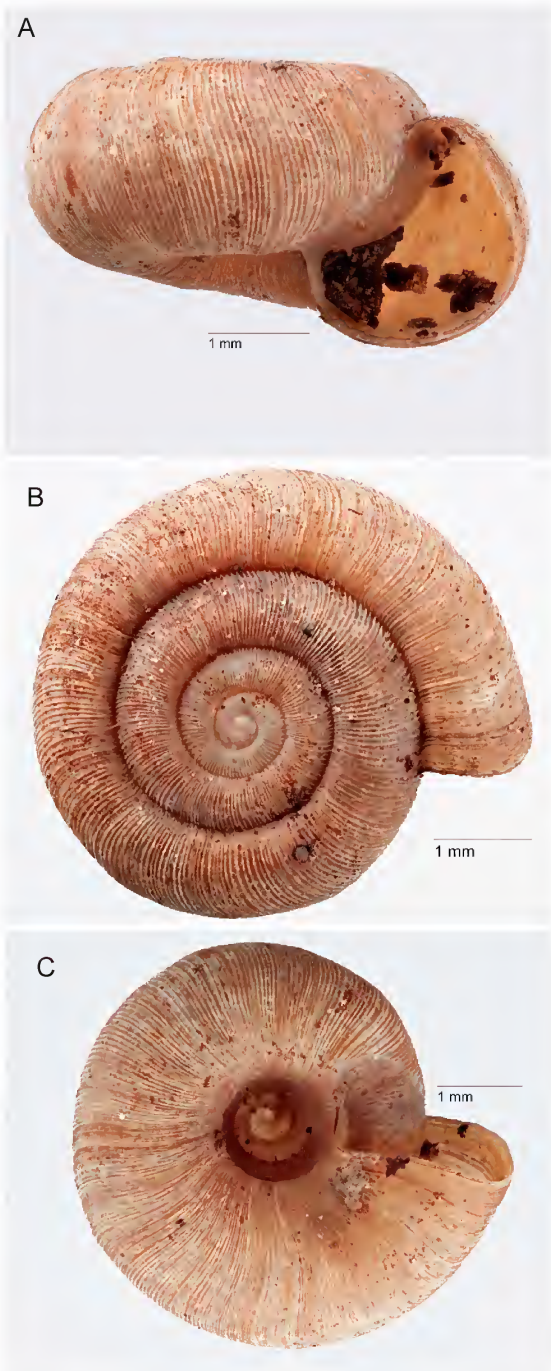


FIG. 5. A-C. *Chordaropa myora* (Stanisic, 2010) comb. nov., QMMO20783, holotype. Scale lines as marked.

Dunwich has a depressed spire, strongly reticulate protoconch sculpture and moderately spaced ribs on the teleoconch. In contrast, *C. myora* from the small patch of rainforest in the Dunwich-Myora area has a flat spire, protoconch with rope-like broad spiral cords and very crowded ribbing on the teleoconch. The two species are endemic to the island but both appear to have congeners on the mainland (Stanisic, unpubl.). This is not surprising considering the relative proximity of the island to the mainland. However, many more mainland taxa will need to be studied before the origins of the two Minjerribah pinwheel snails can be determined.

DISCUSSION

In mainland eastern Australia (New South Wales and Queensland) 163 species of Charopidae have hitherto been documented (Stanisic *et al.* 2010). However there are over 350 unnamed putative species from this region in the Queensland Museum collections (Stanisic, pers. obs.). A further 69 species have been recorded from the rest of the continent but there are numerous species still to be described from the wet forests of Tasmania (Kevin Bonham, pers. comm.), Victoria (Stanisic pers. obs.) and Western Australia (Solem 1983). With less than half the known charopid fauna described, and with the many putative species in museum collections, the need for new species descriptions is compelling if only to begin the task of reducing the taxonomic backlog. However, species description requires generic assignment and that creates a problem for some groups when datasets consist solely of shells.

Generic classification of the Australian Charopidae

The three species dealt with herein are all considered to represent new genera based on their novel patterns of protoconch microsculpture. The fine architecture of this embryonic element of the charopid shell has been shown to be strongly indicative of generic differentiation within the family (Stanisic 1990, Hyman & Stanisic 2005, Shea *et al.* 2012).

Until recently, generic classifications in the family have been for the most part, less than informative. This has led to an unsatisfactory jumble of stand-alone, broadly defined, often polyphyletic generic units (e.g. Iredale 1937a, b). Historical classifications of the Charopidae are largely flawed by a shell-based morphology based on general shell form most often described as 'strongly ribbed, discoidal with an open umbilicus'. Without exception these approaches are characterised by a lack of attention to the many nuances of other shell characters such as protoconch and teleoconch microsculpture and coiling pattern (see Hedley 1924; Iredale 1937a,b, 1939, 1941; Smith & Kershaw 1979).

In particular, the microsculptural architecture of the protoconch in the Charopidae has, in the past, often been treated as a secondary character with descriptions of this feature limited to broad terms such as spiral, radial or cancellate/reticulate (a combination of both spiral and radial). Recent studies have shown that there are many, often subtle, variations on these broad themes that represent distinct generic-level differences between groups of species. These variations are not discernible with light microscopy even at the highest magnification and need to be interpreted with SEM which was not available to many former researchers.

Solem (1970) was the first land snail worker to formally introduce SEM to the study of the micro-architecture of tiny snails such as the Charopidae. One of Solem's first comments was to suggest that protoconch microsculpture could provide useful data for generic groupings within the tiny endodontoid land snails. Solem's (1976, 1983) classic monographs on the endodontid, punctid and charopid land snails of the Pacific Islands are illustrative of the informative detail one can extract from shell examination using SEM. These elaborate studies highlighted the significance of protoconch microsculpture in generic diagnosis. In the Australian sphere Smith & Kershaw (1985) were the first to exploit SEM for the description of three Tasmanian charopid genera. However, these authors provided only broad detail of the protoconch microsculpture with little accompanying illustration and

critical interpretation, e.g. 'radially closely liriate, spirally liriate or decussate'... 'radial and spiral lines'... 'fine radial lines to smooth'.

Recent studies

Stanisic (1990) was the first major study of the Australian Charopidae using SEM to elucidate shell sculptural detail (in combination with anatomy) and the first to allude to a correlation between protoconch microsculpture and generic integrity. This study investigated the sculptural detail of 50 species of subtropical eastern Australian Charopidae and defined 18 genera on the basis of reproductive anatomy and detailed protoconch and teleoconch microsculpture. Hyman & Stanisic (2005), in a study that investigated 32 mainly limestone species in eastern NSW, found that protoconch microsculpture was critical in defining the 11 new genera of Charopidae introduced. More recently, the landmark study of Shea *et al.* (2012) used molecular analyses in addition to shell microsculpture and reproductive anatomy to propose a molecular-based phylogeny for a small cohort of '*Gyrocochlea*' species and their allies. Once again protoconch microsculpture was shown to be a key element in defining the eight new genera that were introduced. The overall conclusion from these studies indicates that it should be possible to confidently propose phylogenetically robust generic units based solely on features of protoconch microsculpture within the Australian Charopidae. This is a significant result for such a mega-diverse family that lives in the litter zone of moist forests and is usually collected as dead shells from litter sorting rather than as mature live individuals for anatomical and molecular studies. A fact highlighted in the current study where the datasets of spirit specimens and many dead shells were made up mainly of immature individuals and shells. The alternative is to keep overloading existing broad groupings, as is the case with *Gyrocochlea* '*sensu* Stanisic *et al.* 2012', to the extent where currently over 100 species could easily be classified in this genus under the broad conchological umbrella of 'generally

brown, radially ribbed, widely umbilicate shell' (Stanisic pers. obs.).

SEM vs. light microscopy interpretation of protoconch microsculpture

The protoconch of *Lithocouperia* gen. nov. when viewed under the light microscope (at 10 × 50 magnification) is very similar to that of *Gyrocochlea* s.s. in showing a 'frosted-glass' pattern. However, when viewed with SEM, the protoconch of *Lithocouperia* reveals a pattern of unconnected, spirally arranged tiny tubercles (Fig. 6A). This contrasts with the fine crowded spirals on the protoconch of *Gyrocochlea* s.s. which when viewed by SEM shows a delicate cancellate pattern comprised of very crowded spiral lirae crossing numerous, very low, somewhat indistinct, fine radial ridglets forming elongate micro-beads at their intersection (Fig. 6B). The protoconch sculpture of *Reticularopa* gen. nov. when viewed with the light microscope resembles that of *Dictyoropa* Shea, Colgan & Stanisic, 2012 from the northern rivers region of north-eastern NSW in showing a reticulate pattern of radial ribs and spiral cords. However, with the assistance of SEM the reticulation of *Reticularopa* is shown to differ by having more widely spaced and more strongly defined radial ribs and spirals cords giving rise to a widely open lattice network (Fig. 6C) when compared with the diffuse low radial ridges and low spiral cords of *Dictyoropa* (Fig. 6D). The protoconch of *Chordaropa* gen. nov. when viewed with the light microscope exhibits a bimodal pattern similar to that of *Diphyoropa* Hyman & Stanisic, 2005 which has low, broad spiral cords initially and low, curved radial ridges that become more prominent toward the protoconch-teleoconch boundary. However, SEM reveals significant differences in the form of the spiral cords and radial ridges of the two genera. Those of *Chordaropa* are low, closely spaced spiral cords and low radial ridges (Fig. 6E) whereas those of *Diphyoropa* are relatively high and widely spaced (Fig. 6F). While at first sight some of these differences may seem points along a continuum and mere 'variations on a theme', each pattern of protoconch microsculpture described above has

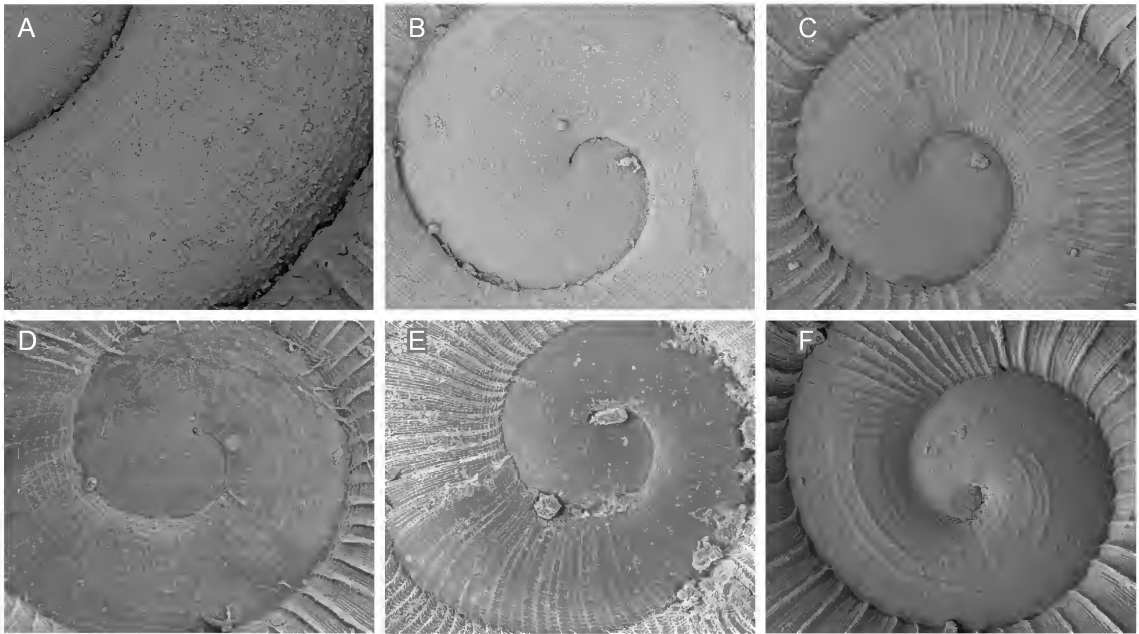


FIG. 6. Protoconch microsculpture. A, *Lithocouperia kalkajaka* sp. nov., QMMO78703, paratype; B, *Gyrocochlea vinitincta* (Cox 1868), AMSC.139752; C, *Reticularopa minjerribah* sp. nov., QMMO70517, paratype; D, *Dictyoropa eurythma* (Hedley 1924), AMSC103618, lectotype; E, *Chordaropa myora* (Stanisic, 2012) comb. nov., QMMO16819, paratype; F, *Diphyoropa saturni* (Cox 1864), AMSC318947.

in most cases, wider species representation in the landscape (geographic consistency) among both described and undescribed species (Shea *et al.* 2012, Stanisic unpubl.). This implies that each distinctive protoconch sculptural pattern essentially signifies a separate radiation of species (= genus).

While these examples clearly support the usefulness of protoconch microsculpture in defining charopid genera they also highlight the degree of difficulty in descriptively defining the various types. The development of a formal and unique set of descriptors for the various types of spiral, radial and reticulate sculptures seems a priority.

It is imperative that more charopids are described in order to make this group accessible to biogeography students and land managers. However, species descriptions must be accompanied by detailed SEM studies of protoconch sculpture, and proposed generic units clearly and formally defined so as to add to the informative phylogenetic frameworks proposed by Hyman & Stanisic (2005) and

Shea *et al.* (2012). There will always be minor areas of contention when it comes to interpreting details of protoconch architecture for generic placement. Convergences, parallelisms and some conservatism in shell-based morphological characters will occasionally emerge to cloud interpretation. However, preliminary examination by the author of all currently recognised Australian charopid genera, indicate that these hurdles will be secondary to the sizeable and principal task of species documentation given the depth of the taxonomic impediment.

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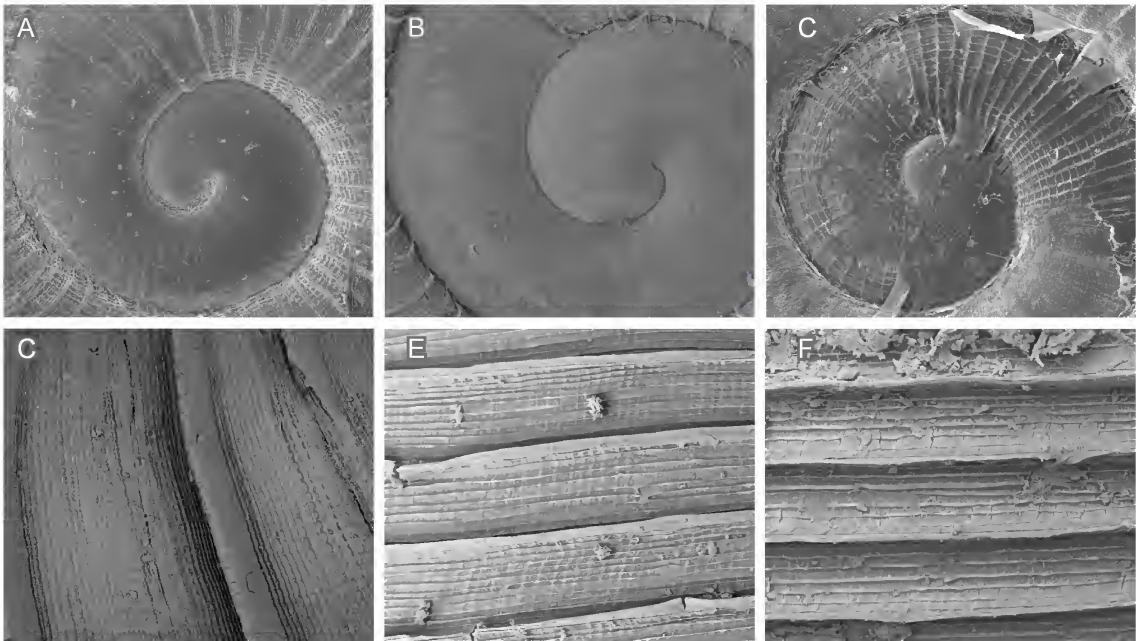


FIG. 7. A-C. Protoconch microsculpture. A, '*Gyrocochlea*' *cinnamea* (Hedley, 1912), AMSC154937; B, *Comboynea boorganna* Shea, Colgan & Stanisic, 2012, QMMO31451, paratype; C, Undescribed charopid, QMMO76839, Brisbane City. D-F, Teleoconch microsculpture. D, *Lithocouperia kalkajaka* sp. nov., QMMO78703, paratype; E, *Reticularopa minjerribah* sp. nov., QMMO70517, paratype; F, *Chordaropa myora* Stanisic, 2010, QMMO16819

Diphyrora saturni are credited to Sue Lindsay, Australian Museum.

CITED LITERATURE

- Hedley, C. 1924. Some notes on Australian land shells. *Australian Zoologist* 3: 215-222.
- Hyman, I.T. & Stanisic, J. 2005. New charopid land snails, chiefly from limestone outcrops in eastern New South Wales (Eupulmonata: Charopidae). *Memoirs of the Queensland Museum* 50: 219-302.
- Iredale, T. 1937a. A basic list of the land Mollusca of Australia. *Australian Zoologist* 8: 287-333.
- 1937b. An annotated checklist of the land shells of south and central Australia. *South Australian Naturalist* 18: 6-56.
1939. A review of the land Mollusca of Western Australia. *Journal of the Royal Society of Western Australia* 25: 1-88.
1941. Guide to the land shells of New South Wales. *Australian Naturalist* 10: 262-269.
- Moulds, M. S. & Olive, J.C. 2014. A new species of *Tamasa* Distant from an unusual cave-like habitat in Australia (Cicadidae: Cicadinae: Tamasini). *Records of the Australian Museum* 66: 265-270.
- Shea, M., Colgan, D. & Stanisic, J. 2012. Systematics of the landsnail genus *Gyrocochlea* and relatives (Mollusca: Charopidae). *Zootaxa* 3585: 1-109.
- Smith, B. J. & Kershaw, R. C. 1979. *Fieldguide to the non-marine molluscs of south-eastern Australia*. (ANU Press: Canberra) 285pp.
1985. Description of three Tasmanian charopid genera (Pulmonata: Mollusca) with notes on their type species. *Records of the Queen Victoria Museum, Launceston* 88: 1-14.
- Solem, A. 1970. Malacological applications of scanning electron microscopy. I. Introduction and shell surface features. *Veliger* 12: 394-400.
1976. Endodontoid land snail from Pacific Islands (Mollusca: Pulmonata; Sigmurethra). Part I. Family Endodontidae. *Fieldiana: Zoology Special Publication*. 508pp.
1983. Endodontoid land snail from Pacific Islands (Mollusca: Pulmonata; Sigmurethra). Part II. Families Punctidae, Charopidae, Zoogeography. (Field Museum of Natural History: Chicago) 336pp.
- Stanisic, J. (1990) Systematics and biogeography of eastern Australian Charopidae (Mollusca: Pulmonata). *Memoirs of the Queensland Museum* 30: 1-241.
- Stanisic, J., Shea, M., Potter, D. and Griffiths, O. 2010. *Australian Land Snails Volume 1: A Field Guide to Eastern Australian Species*. (Bioculture Press: Mauritius) 596pp.